Supplemental Online Content:
Risk adjustment in Medicare ACO program deters coding increases but may lead ACOs to drop high-risk beneficiaries

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Supplemental Methods

Within-beneficiary changes in risk score. We tested for changes in coding intensity by evaluating the association between beneficiary MSSP exposure and within-beneficiary changes in risk score over time. We estimated a linear regression model that included a time-varying indicator of cumulative MSSP exposure, beneficiary fixed effects, year fixed effects (to control for secular trends), and time-varying area-level characteristics (poverty, education, Medicare Advantage penetration). These models omitted demographic variables included in the risk score algorithm (age, sex, Medicaid dual eligibility, disability) to avoid over-adjustment.

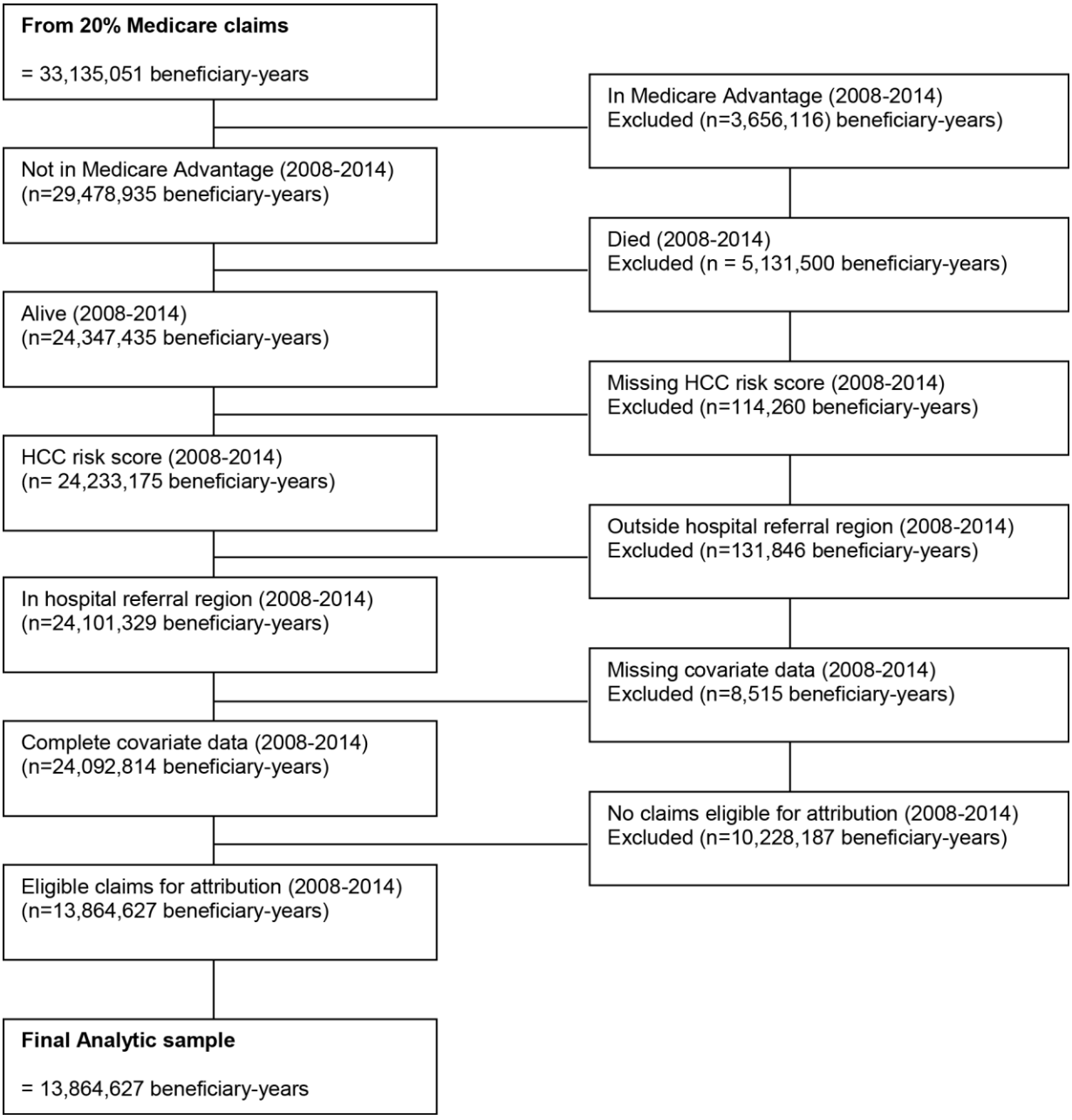
We tested for variation in the effect of the MSSP on within-beneficiary risk scores in the following manner: 1) estimated an interaction model that included an interaction term between the MSSP indicator and the ACO or beneficiary characteristic to the base regression model (explained in the text); 2) estimated risk score changes for each group; 3) formally tested for differential risk score changes across groups. Percent change in HCC risk score was measured as the estimated change in risk score relative to the average adjusted risk score for MSSP beneficiaries in 2011 (prior to the program's start).

Analysis of clinician average patient panel risk and entry and exit in the MSSP. We evaluated the relationship between the clinician's patient panel and entry and exit in the MSSP in the following manner. First, we defined clinician participation in the MSSP using CMS' Shared Savings Program Provider-Level Research Identifiable File, which lists the ACOs, provider groups, and clinicians participating in the MSSP. Second, defined each clinician's patient panel, adapting MSSP attribution specifications to directly beneficiaries to the clinician from whom they received the plurality of eligible evaluation and management services (Healthcare Common Procedure Coding System codes: 99201 through 99215; 99304 through 99350; G0402; G0438; and G0439.) Finally, we estimated the probability of clinician entry or exit as a function of the clinician's patient panel's average risk score, year fixed effects, market fixed effects, and average patient characteristics (age, sex, race/ethnicity, disability, end-stage renal disease, dual-eligibility for Medicaid, and area-level poverty, education, and Medicare Advantage penetration).

Analyses of MSSP entry were restricted to clinicians not participating in the MSSP during the year prior to analysis and did not include ACO formation, i.e., participation in an ACO's

first contract year. Analyses of MSSP exit were restricted to clinicians participating in the MSSP during the year prior to analysis. Both sets of analyses were restricted to ACOs entering MSSP contracts in 2012 or 2013, as 2012-2014 MSSP data could not be used to determine clinician exit or entry for ACOs formed in 2014. These analyses also required that clinicians have beneficiaries attributed to their patient panel in the analytic year(s), thus excluding clinicians who exit the MSSP due to retirement or death, for example. To improve statistical reliability of clinician-level estimates, our main specification used average patient characteristics in the three years prior to determination of MSSP entry or exit. We obtained similar results when using average patient characteristics in the prior year, average patient characteristics in the prior two years, or when weighting by the size of clinician's patient panel.

Exhibit A1. CONSORT diagram

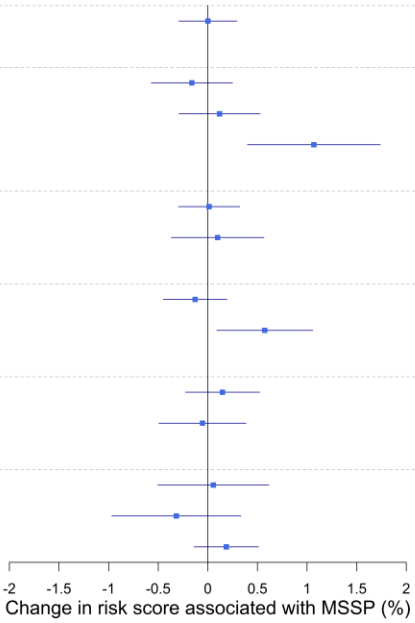


SOURCE: Authors' analysis of 2008-2014 data from: 20% sample of Medicare claims; the American Community Survey; CMS' Beneficiary-level Shared Savings Program File; Leavitt Partners ACO Database; CMS' Shared Savings Program Public-Use File.
NOTES: HCC is Hierarchical Condition Category.

Exhibit A2. Sensitivity analyses of association between beneficiary attribution to the MSSP and coded risk

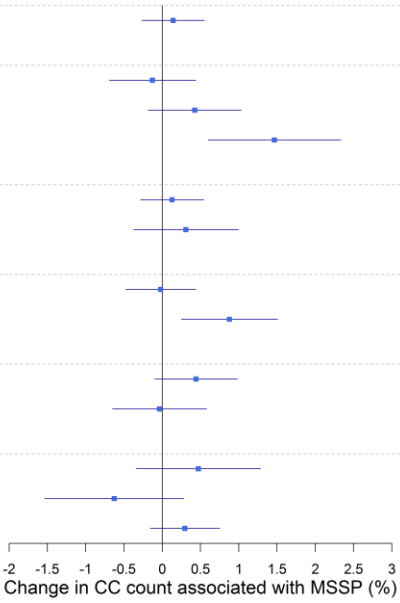
Panel A. Change in HCC risk score

Characteristic	Mean Controls (2011)	Mean MSSP (2011)	Change in risk score (95% CI)	Change relative to base (95% CI)
Average change	1.159	1.159	0.0 (-0.3, 0.3)	N/A
MSSP Cohort				
2012	1.168	1.166	-0.2 (-0.6, 0.2)	--
2013	1.143	1.144	0.1 (-0.3, 0.5)	0.2 (-0.4, 0.8)
2014	1.151	1.164	1.1 (0.4, 1.7)	1.5 (0.8, 2.3)
Earned shared savings				
No	1.148	1.148	0.0 (-0.3, 0.3)	--
Yes	1.181	1.182	0.1 (-0.4, 0.6)	0.0 (-0.5, 0.5)
High Medicare Advantage area				
No	1.159	1.158	-0.1 (-0.4, 0.2)	--
Yes	1.158	1.165	0.6 (0.1, 1.1)	0.8 (0.3, 1.3)
Commercial ACO contract				
No	1.164	1.165	0.1 (-0.2, 0.5)	--
Yes	1.153	1.153	-0.1 (-0.5, 0.4)	-0.3 (-0.9, 0.3)
Organizational structure				
Physician-led	1.171	1.172	0.1 (-0.5, 0.6)	--
Hospital-led	1.151	1.147	-0.3 (-1.0, 0.3)	-0.5 (-1.3, 0.3)
Physician-hospital partnership	1.153	1.155	0.2 (-0.1, 0.5)	0.1 (-0.6, 0.7)



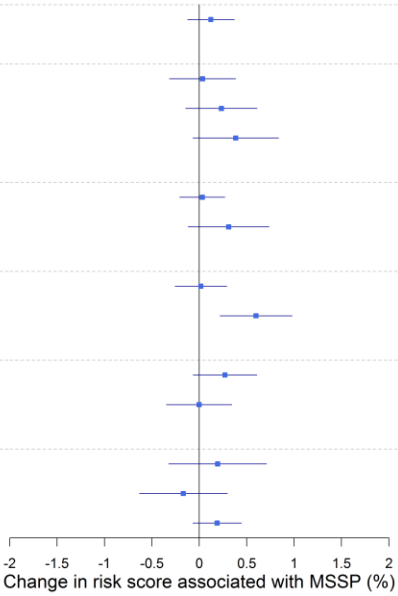
Panel B. Change in count of Condition Categories (CC)

Characteristic	Mean Controls (2011)	Mean MSSP (2011)	Change in risk score (95% CI)	Change relative to base (95% CI)
Average change	2.057	2.060	0.1 (-0.3, 0.6)	N/A
MSSP Cohort				
2012	2.081	2.078	-0.1 (-0.7, 0.4)	--
2013	2.010	2.019	0.4 (-0.2, 1.0)	0.4 (-0.4, 1.3)
2014	2.044	2.074	1.5 (0.6, 2.3)	2.0 (0.9, 3.0)
Earned shared savings				
No	2.024	2.026	0.1 (-0.3, 0.5)	--
Yes	2.123	2.130	0.3 (-0.4, 1.0)	0.1 (-0.6, 0.8)
High Medicare Advantage area				
No	2.061	2.060	0.0 (-0.5, 0.4)	--
Yes	2.042	2.060	0.9 (0.3, 1.5)	1.2 (0.5, 1.8)
Commercial ACO contract				
No	2.072	2.081	0.4 (-0.1, 1.0)	--
Yes	2.038	2.038	0.0 (-0.6, 0.6)	-0.6 (-1.4, 0.3)
Organizational structure				
Physician-led	2.097	2.107	0.5 (-0.3, 1.3)	--
Hospital-led	2.040	2.027	-0.6 (-1.5, 0.3)	-1.2 (-2.4, 0.0)
Physician-hospital partnership	2.032	2.038	0.3 (-0.2, 0.7)	-0.2 (-1.2, 0.7)



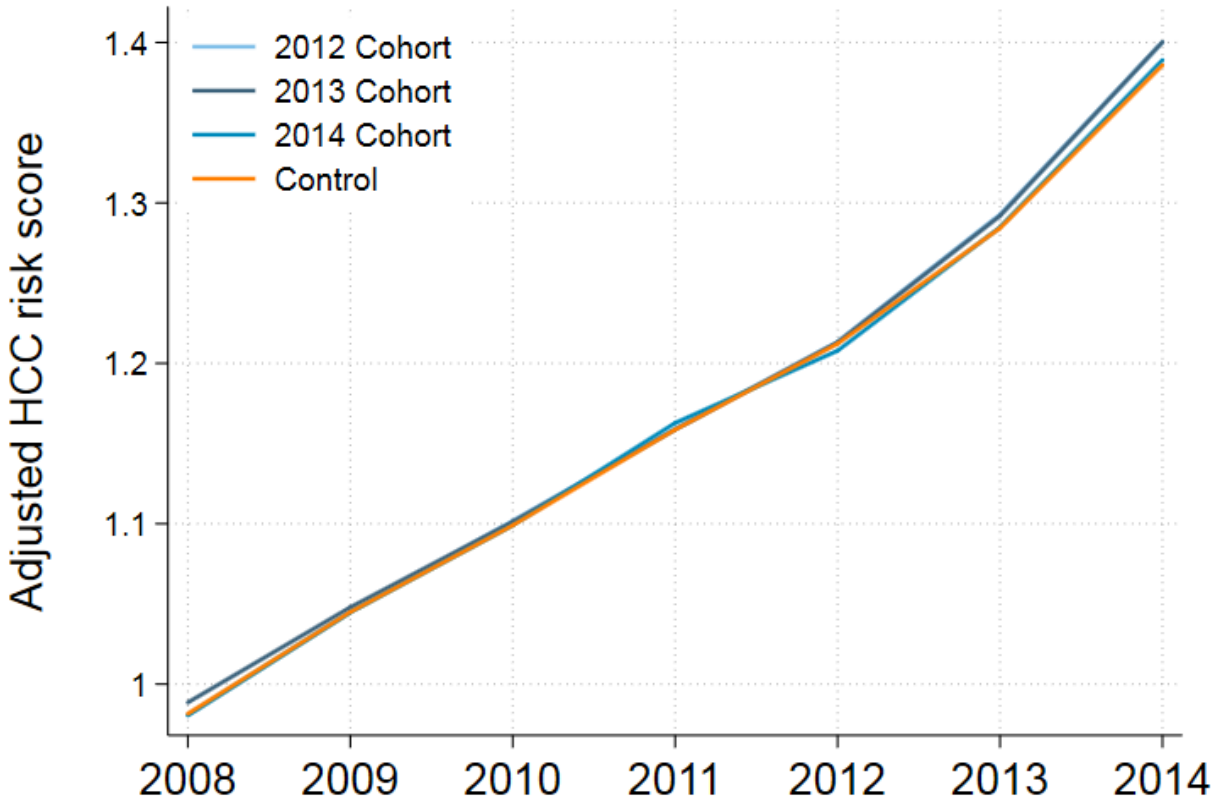
Panel C. Change in HCC risk score normalized by total price-standardized spending

Characteristic	Mean Controls (2011)	Mean MSSP (2011)	Change in risk score (95% CI)	Change relative to base (95% CI)
Average change	1.158	1.160	0.1 (-0.1, 0.4)	N/A
MSSP Cohort				
2012	1.165	1.166	0.0 (-0.3, 0.4)	--
2013	1.147	1.150	0.2 (-0.1, 0.6)	0.2 (-0.3, 0.7)
2014	1.157	1.162	0.4 (-0.1, 0.8)	0.4 (-0.2, 1.0)
Earned shared savings				
No	1.152	1.152	0.0 (-0.2, 0.3)	--
Yes	1.172	1.176	0.3 (-0.1, 0.7)	0.3 (-0.1, 0.7)
High Medicare Advantage area				
No	1.159	1.159	0.0 (-0.3, 0.3)	--
Yes	1.156	1.163	0.6 (0.2, 1.0)	1.0 (0.6, 1.4)
Commercial ACO contract				
No	1.162	1.165	0.3 (-0.1, 0.6)	--
Yes	1.155	1.154	0.0 (-0.3, 0.3)	-0.3 (-0.8, 0.2)
Organizational structure				
Physician-led	1.168	1.170	0.2 (-0.3, 0.7)	--
Hospital-led	1.152	1.150	-0.2 (-0.6, 0.3)	-0.5 (-1.1, 0.2)
Physician-hospital partnership	1.155	1.157	0.2 (-0.1, 0.4)	-0.1 (-0.7, 0.5)



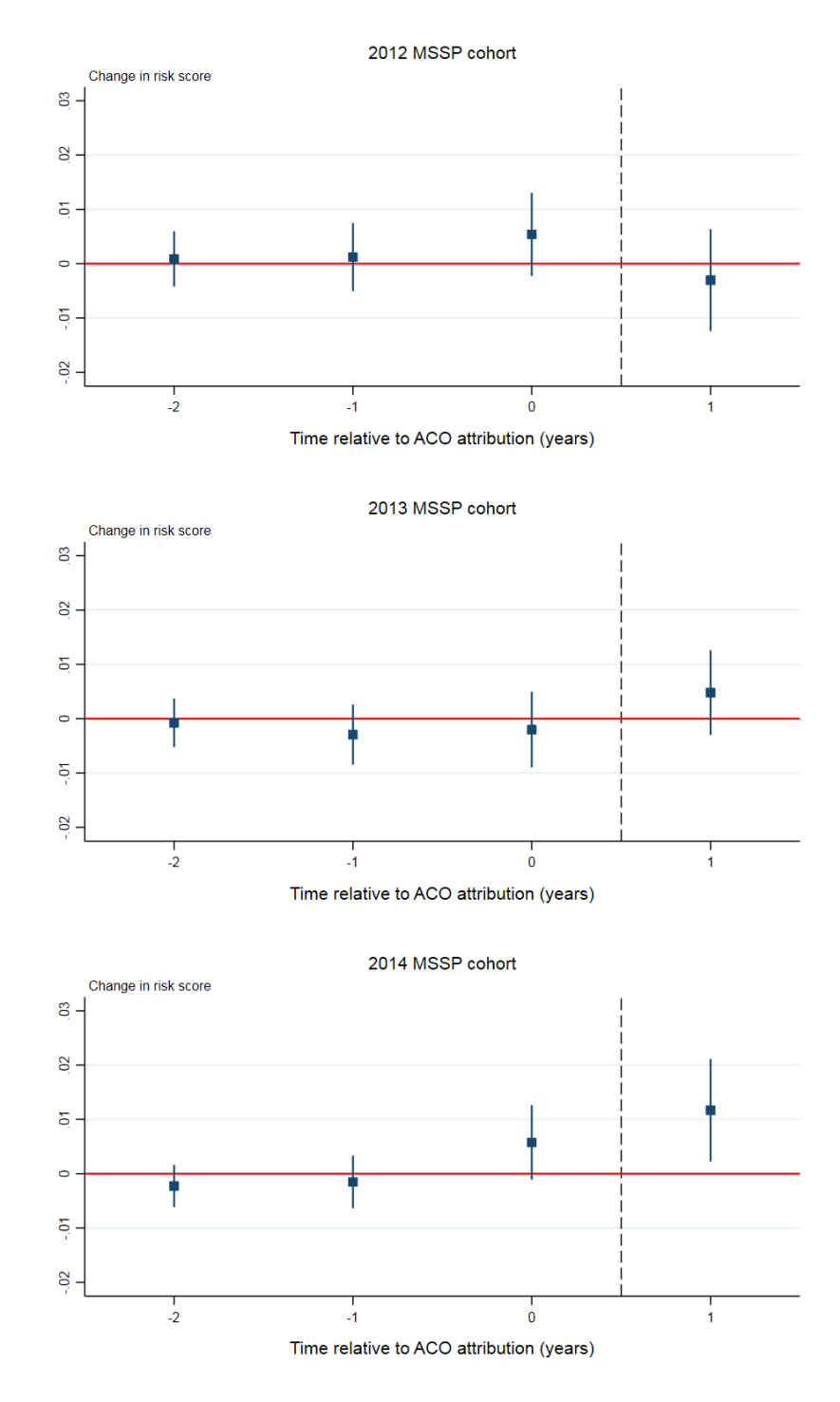
SOURCE: Authors' analysis of 2008-2014 data from: 20% sample of Medicare claims; the American Community Survey; CMS' Beneficiary-level Shared Savings Program File; Leavitt Partners ACO Database; CMS' Shared Savings Program Public-Use File.
NOTES: Model specification is provided in the main text. High Medicare Advantage penetration was defined as residing in a county > 80th percentile for the share of fee-for-service beneficiaries enrolled in Medicare Advantage. Percent change in risk score was measured as the estimated change in risk score relative to the average adjust risk score for MSSP beneficiaries in 2011 (prior to the program's start). To better isolate the influence of coding on risk score, we estimated changes in the risk score component plausibly affected by coding practice (i.e., the count of Condition Categories that originate from provider-reported diagnoses) and excluded the components originating from administrative data (e.g., age, sex, disability status) (Panel A). Because ACOs also have an incentive to lower spending in the MSSP, we also evaluated changes in risk scores normalized by total price-standardized spending (Panel B). Total annual spending was the sum of spending for inpatient, outpatient, professional, and skilled nursing facility services and was price-standardized to account for variation resulting from regional wage indices and payments for indirect medical education, Disproportionate Share Hospitals, and new technologies. The error bars indicate 95% confidence intervals. MSSP is Medicare Shared Saving Program. ACO is accountable care organization. CC is Condition Category.

Exhibit A3. Trends in risk score across MSSP vs. non-MSSP beneficiaries (2008-2014)



SOURCE: Authors' analysis of 2008-2014 data from: 20% sample of Medicare claims; the American Community Survey; CMS' Beneficiary-level Shared Savings Program File.
NOTES: These analyses graphed trends in adjusted risk score across four groups of beneficiaries: beneficiaries who joined in the MSSP in 2012; beneficiaries who joined in the MSSP in 2013; beneficiaries who joined in the MSSP in 2014; and controls who were never in the MSSP. Adjusted risk score was estimated using a model that included beneficiary fixed effects, time-varying area-level characteristics, an indicator for each year, an indicator for MSSP cohort (2012 cohort, 2013 cohort, 2014 cohort, control), and an interaction term between MSSP cohort and the year of interest, but did not impose an underlying time trend. From these models, Stata's -margins- command was used to estimate predicted risk score for each cohort and in each year. The error bars indicate 95% confidence intervals. MSSP is Medicare Shared Saving Program. HCC is Hierarchical Condition Category.

Exhibit A4. Event study of change in risk score before and after attribution to the MSSP



SOURCE: Authors' analysis of 2008-2014 data from: 20% sample of Medicare claims; the American Community Survey; CMS' Beneficiary-level Shared Savings Program File.

NOTES: We performed an event study to test for differential changes in risk score between MSSP beneficiaries vs. controls in the years prior to beneficiary attribution to MSSP ACOs. Estimates represent the association between eventual attribution to the MSSP and change in risk score in the years prior to and following attribution. Estimates are from a regression that includes indicators for the interaction between beneficiary MSSP attribution (ever/never) and time relative to MSSP attribution (where 1 = first year of attribution to MSSP), with additional controls for beneficiary fixed effects, year fixed effects, and time-varying beneficiary characteristics (described in main text). The error bars indicate 95% confidence intervals. MSSP is Medicare Shared Saving Program. ACO is accountable care organization.

Exhibit A5. Characteristics of Medicare beneficiaries in the analytic sample vs. excluded sample (2008-2011).

Characteristics	Analytic sample (N=13,864,627)	Excluded sample (N=19,270,424)	P value
Patient characteristics	Unadjusted mean	Unadjusted mean	
Age, y (SD)	74.3 (10.6)	71.5 (12.8)	<0.001
Female	60.7%	56.5%	<0.001
Race/Ethnicity	86.2%		
Non-Hispanic white	86.2%	80.5%	<0.001
Non-Hispanic black	7.2%	9.8%	
Hispanic	3.7%	5.9%	
Other	2.9%	3.8%	
Dual-eligibility for Medicaid (months per year)	1.8 (4.2)	2.5 (4.7)	<0.001
Disability	19.7%	24.5%	<0.001
End-stage renal disease	0.4%	1.4%	<0.001
Area-level characteristics	23.1 (12.8)		
Medicare Advantage	23.1 (12.8)	23.8 (13.2)	<0.001
Below federal poverty level	13.9 (8.5)	14.8 (9.1)	<0.001
With high school degree	28.6 (16.0)	27.4 (15.9)	<0.001
With college degree	86.9 (8.3)	86.0 (9.0)	<0.001
Beneficiary outcomes	1.167 (0.901)		

HCC risk score	1.167	(0.901)	1.235 (1.142)	<0.001
Total annual spending	7,507	(14,329)	10,819 (21,725)	<0.001

SOURCE: Authors' analysis of 2008-2014 data from: 20% sample of Medicare claims; the American Community Survey; CMS' Beneficiary-level Shared Savings Program File.
NOTES: Study inclusion and exclusion criteria for analytic sample are described in the main text.

Exhibit A6. Relationship between beneficiary risk score and beneficiary exit or entry in the MSSP

Average risk score in prior year	Probability of beneficiary entering MSSP, % (95% CI)	Risk difference: Pr(entry|Nth percentile) - Pr(entry|50th percentile)	P value	Risk ratio: Pr(entry|Nth percentile) /Pr(entry|50th percentile)	P value
1st percentile	4.1 (4.0, 4.3)	-0.3	0.002	0.94	<0.001
5th percentile	4.3 (4.2, 4.3)	-0.2	<0.001	0.96	<0.001
10th percentile	4.3 (4.3, 4.4)	-0.1	<0.001	0.97	<0.001
25th percentile	4.4 (4.4, 4.4)	0.0	<0.001	0.99	<0.001
50th percentile	4.4 (4.4, 4.4)	--	--	--	--
75th percentile	4.5 (4.5, 4.5)	0.1	<0.001	1.02	<0.001
90th percentile	4.7 (4.6, 4.7)	0.2	<0.001	1.05	<0.001
95th percentile	4.8 (4.7, 4.9)	0.4	<0.001	1.09	<0.001
99th percentile	5.4 (5.1, 5.6)	1.0	<0.001	1.21	<0.001

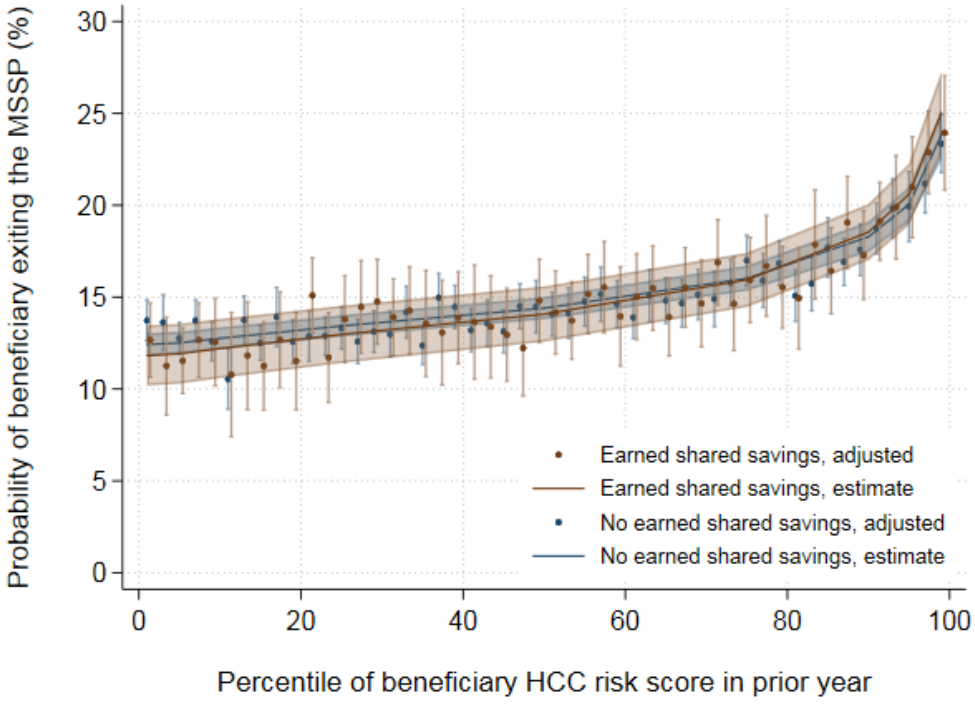
Average risk score in prior year	Probability of beneficiary exiting MSSP, % (95% CI)	Risk difference: Pr(exit|Nth percentile) - Pr(exit|50th percentile)	P value	Risk ratio: Pr(exit|Nth percentile) /Pr(exit|50th percentile)
1st percentile	13.9 (13.5, 14.3)	-2.1	<0.001	0.87	<0.001

5th percentile	14.0 (13.7, 14.3)	-2.0	<0.001	0.88	<0.001
10th percentile	14.3 (14.0, 14.6)	-1.7	<0.001	0.89	<0.001
25th percentile	15.0 (14.8, 15.2)	-1.0	<0.001	0.94	<0.001
50th percentile	16.0 (15.9, 16.0)	--	--	--	--
75th percentile	17.6 (17.4, 17.8)	1.7	<0.001	1.10	<0.001
90th percentile	19.9 (19.5, 20.3)	3.9	<0.001	1.25	<0.001
95th percentile	21.6 (21.0, 22.2)	5.6	<0.001	1.35	<0.001
99th percentile	25.1 (24.1, 26.1)	9.1	<0.001	1.57	<0.001

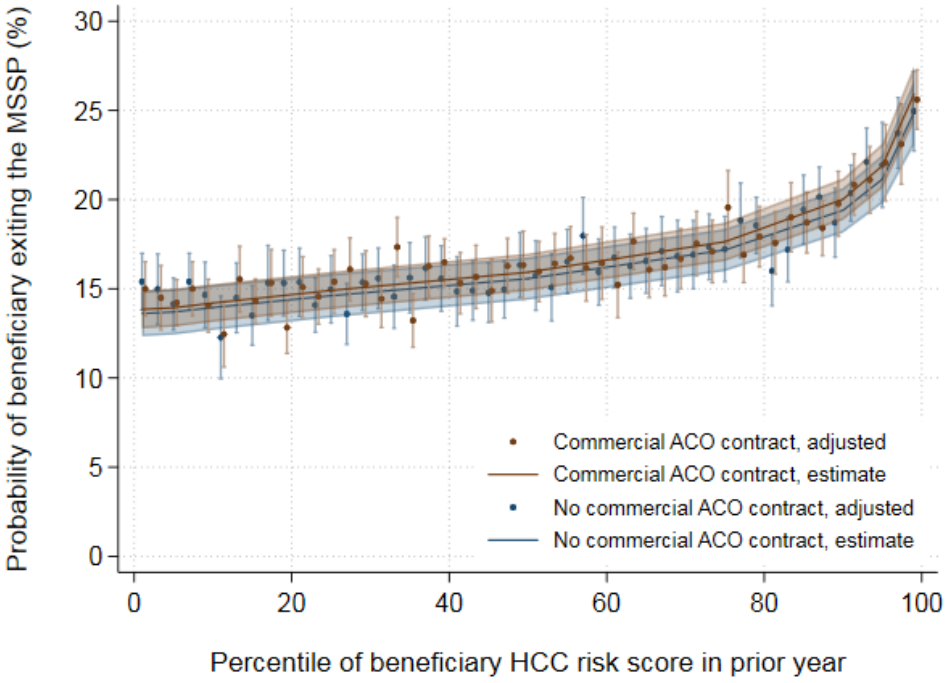
SOURCE: Authors' analysis of 2012-2014 data from: 20% sample of Medicare claims; the American Community Survey; CMS' Beneficiary-level Shared Savings Program File.
NOTES: Model specification is described in the Main Text. From these models, we estimated the probability of MSSP entry or exit across beneficiaries at the 1st, 5th, 10th, 25th, 50th, 75th, 90th, 99th, and 99th percentile of prior-year risk score. Risk ratios and risk differences were calculated by testing the difference between the probability of beneficiary exit or entry at a given risk score percentile (e.g., 95th percentile) vs. the probability of beneficiary exit or entry at the median risk score (50th percentile). MSSP is Medicare Shared Saving Program. ACO is accountable care organization.

Exhibit A7. Heterogeneity in relationship between beneficiary risk score and exit from Medicare Shared Savings Program (MSSP)

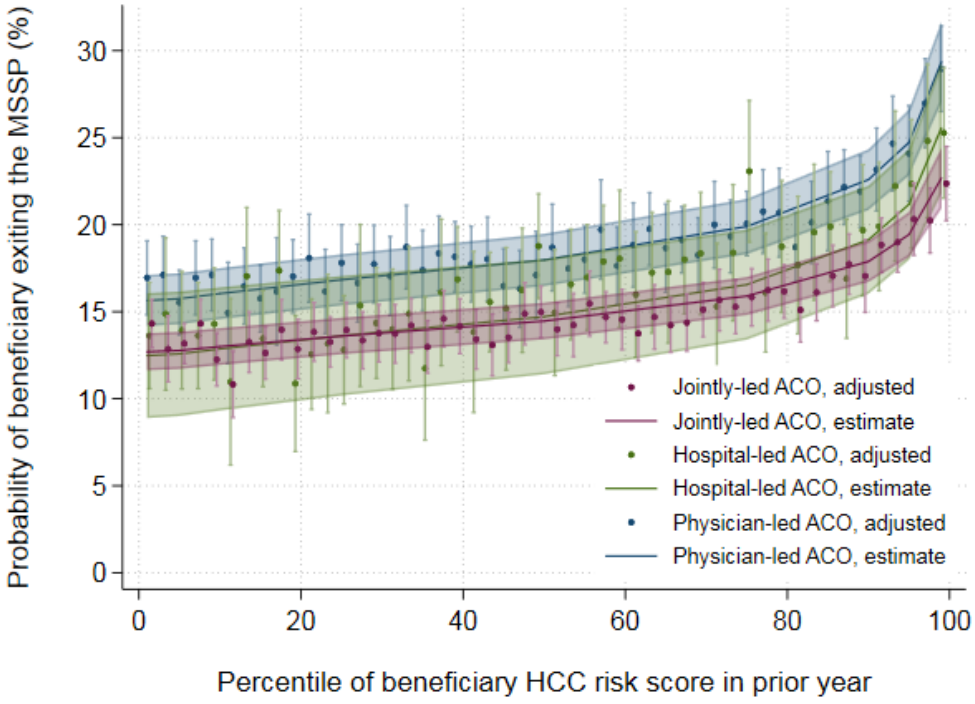
Panel A. ACO earned shared savings



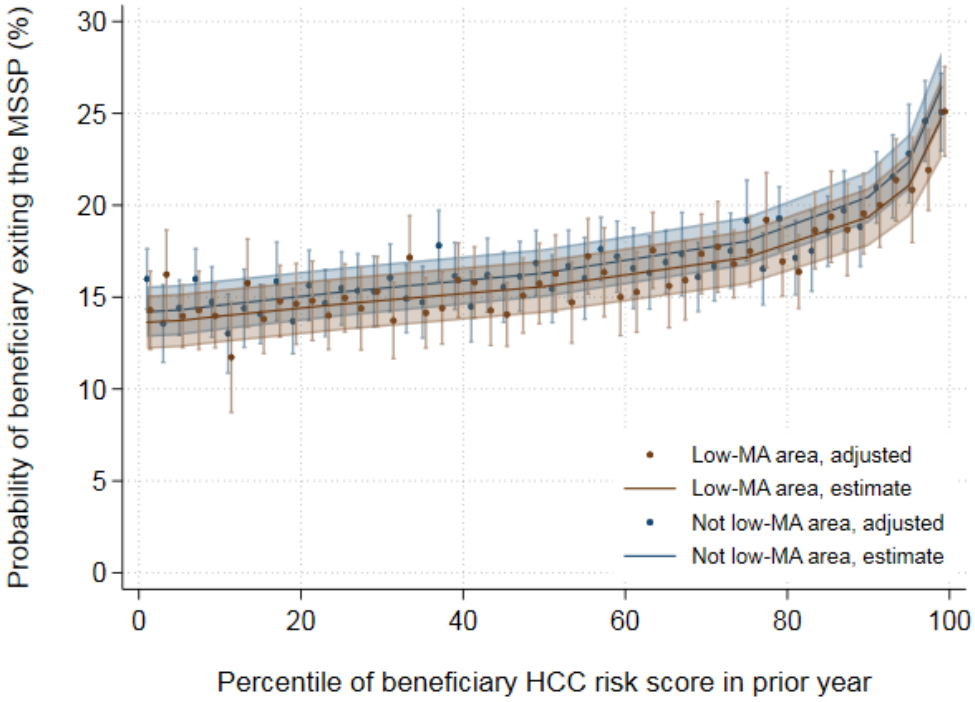
Panel B. Concurrent commercial ACO contracts



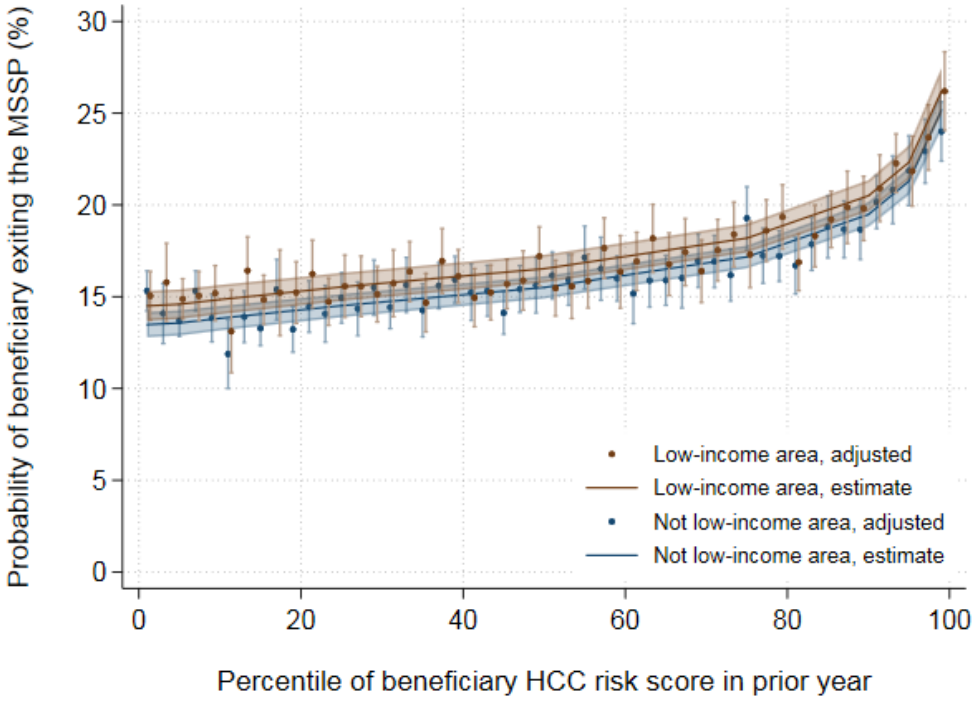
Panel C. ACO organizational structure



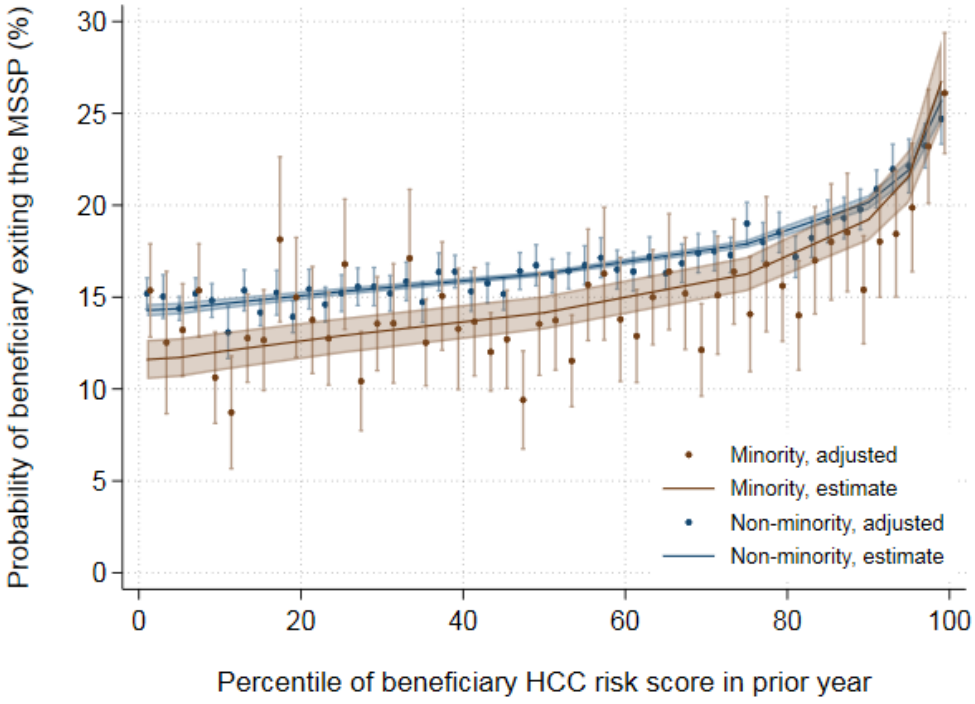
Panel D. Beneficiary county-level Medicare Advantage (MA) penetration



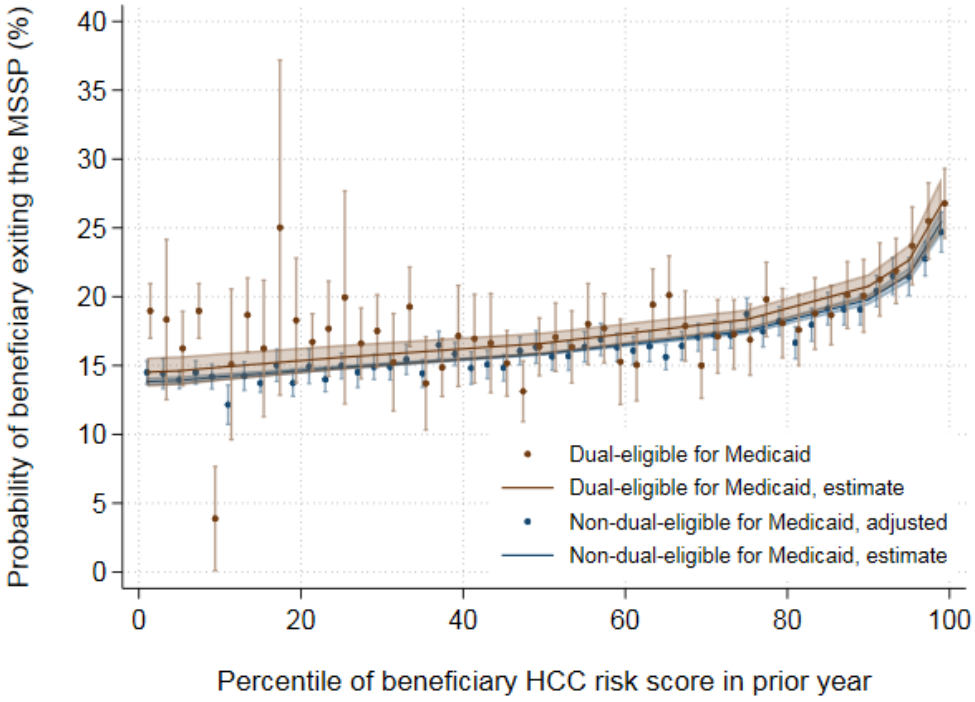
Panel E. Beneficiary area-level income



Panel F. Beneficiary minority status



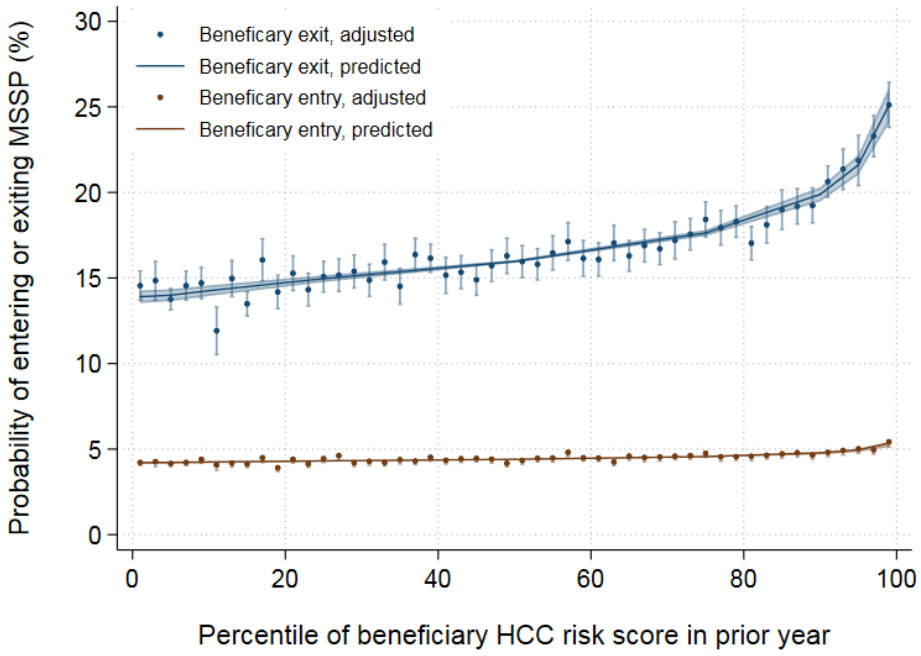
Panel G. Beneficiary dual-eligibility for Medicaid



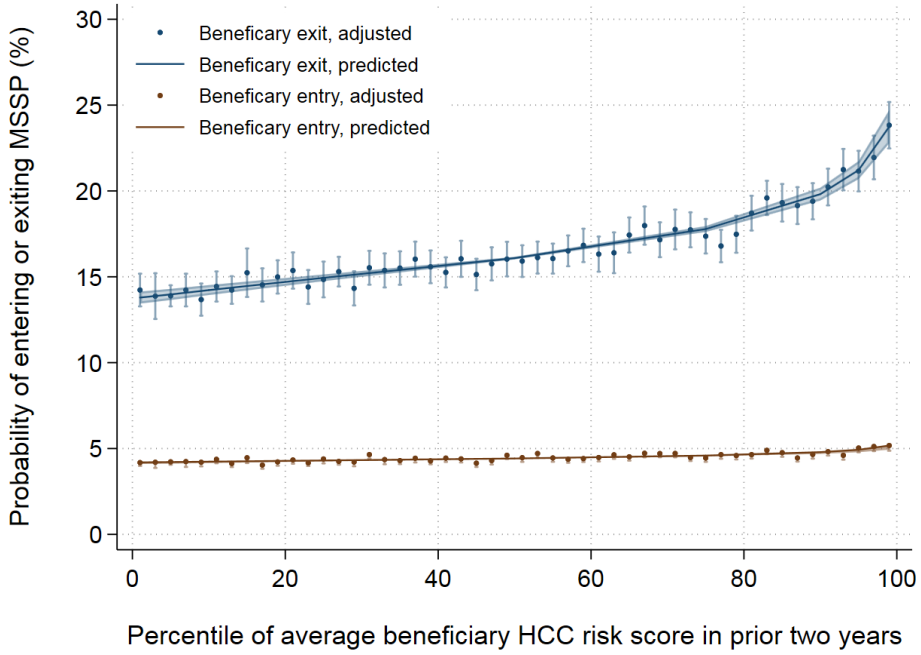
SOURCE: Authors' analysis of 2012-2014 data from: 20% sample of Medicare claims; the American Community Survey; CMS' Beneficiary-level Shared Savings Program File.
NOTES: To measure heterogeneity in the relationship between risk score and exit, we estimated a single fully-interacted model that added to the base regression model (explained in the text) a series of interaction terms between risk score and each ACO and beneficiary characteristic listed in the exhibits. From this fully-interacted model, we estimated the probability of MSSP exit for beneficiaries in each group (e.g., in ACOs that earned shared savings) at the 1st, 5th, 10th, 25th, 50th, 75th, 90th, 99th, and 99th percentile of prior-year risk score. The error bars indicate 95% confidence intervals. MSSP is Medicare Shared Saving Program. ACO is accountable care organization. HCC is Hierarchical Condition Category.

Exhibit A8. Sensitivity analyses of beneficiary entry and exit in the MSSP

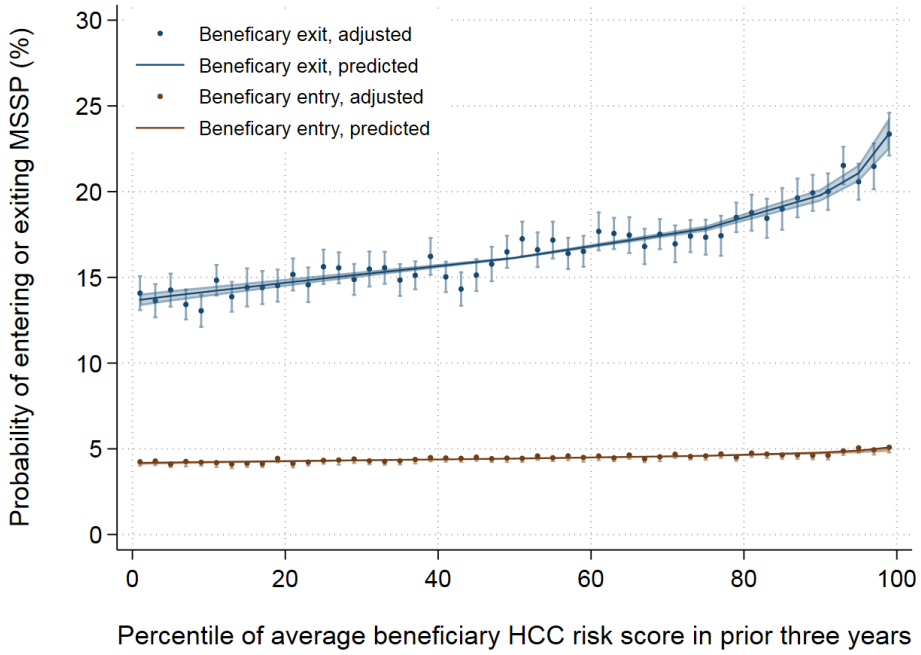
Panel A. Risk score in prior year



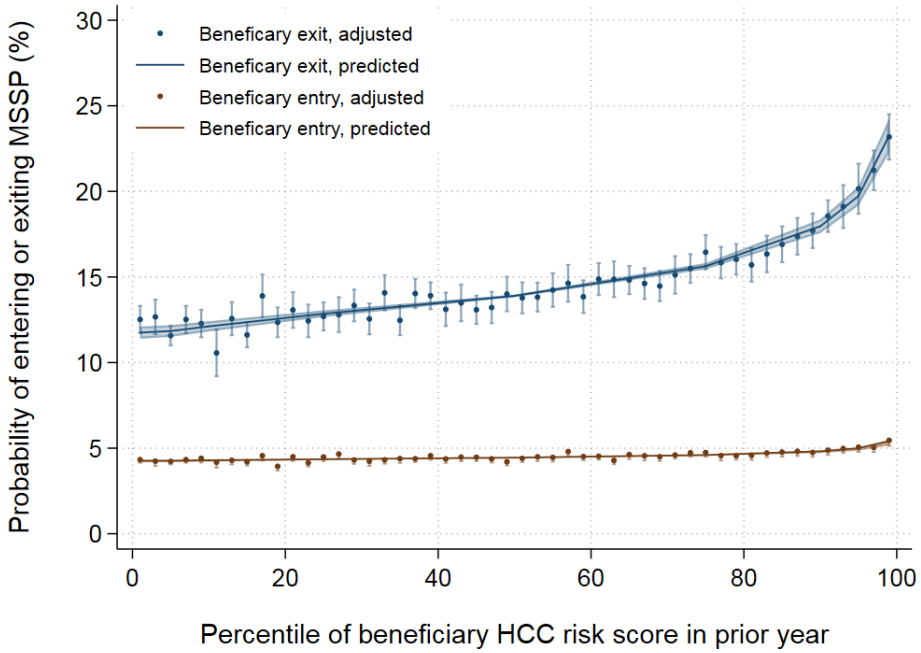
Panel B. Risk score in prior two years



Panel C. Risk score in prior three years



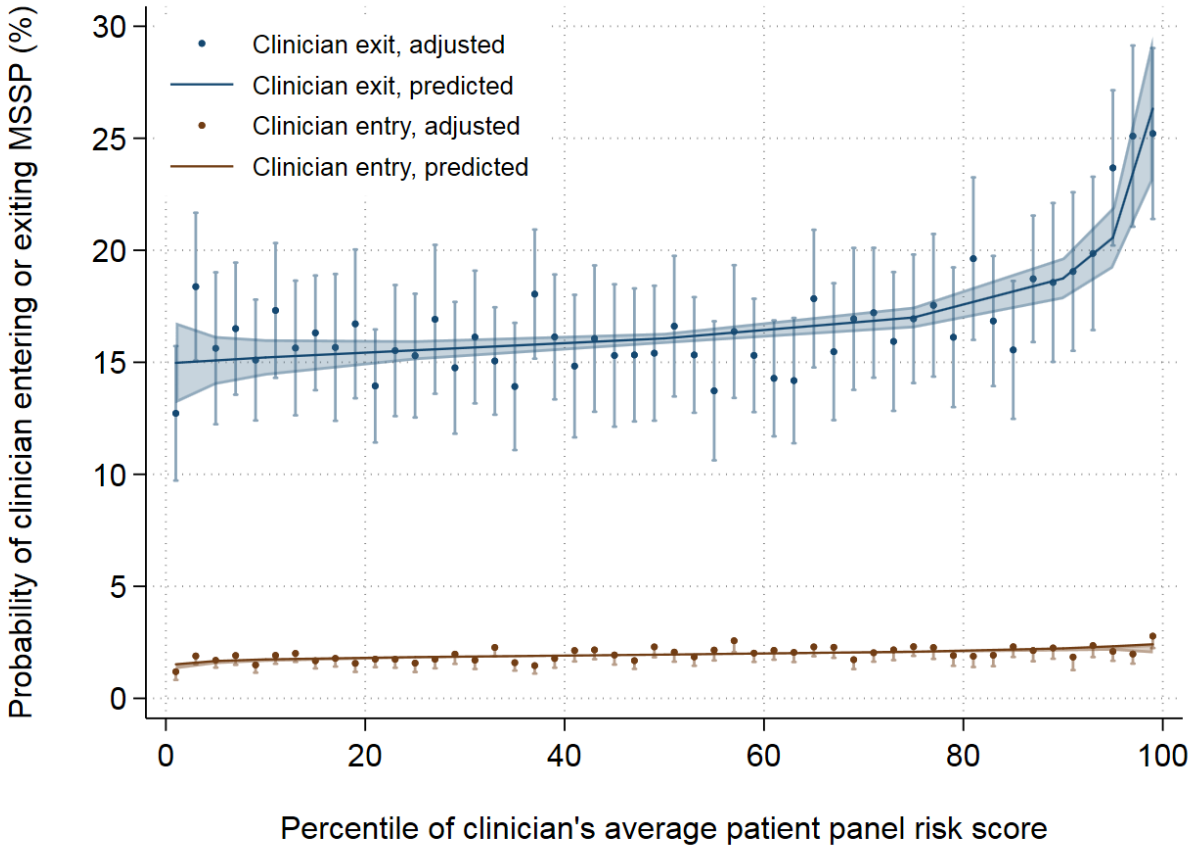
Panel D. Among beneficiaries attributed via claims submitted by a primary care clinician in the outpatient setting



SOURCE: Authors' analysis of 2012-2014 data from: 20% sample of Medicare claims; the American Community Survey; CMS' Beneficiary-level Shared Savings Program File.

NOTES: Models are estimated as described in the main text. The error bars indicate 95% confidence intervals. MSSP is Medicare Shared Saving Program. HCC is Hierarchical Condition Category.

Exhibit A9. Relationship between clinician's average patient panel risk score and clinician entry and exit in the MSSP



SOURCE: Authors' analysis of 2012-2014 data from: 20% sample of Medicare claims; the American Community Survey; CMS' Provider-level Shared Savings Program File.
NOTES: Model specification is described in the Supplemental Methods. The error bars indicate 95% confidence intervals. MSSP is Medicare Shared Saving Program.

Exhibit A10. Growth in risk score and beneficiary entry and exit in the MSSP (2012-2014)

	Growth in beneficiary risk score between 2012 and 2013 (%)	**P value**	**Growth in beneficiary risk score between 2013 and 2014 (%)**	**P value**
MSSP status	**Risk growth across MSSP status (%)**		**Risk growth across MSSP status (%)**	
Never in MSSP	3.7 (3.5, 3.8)	<0.001	5.8 (5.6, 6.0)	<0.001
Always in MSSP	3.3 (3.0, 3.7)	<0.001	5.6 (5.2, 6.0)	<0.001
Entered MSSP	5.5 (4.9, 6.1)	<0.001	7.2 (6.4, 7.9)	<0.001
Exited MSSP	8.2 (7.2, 9.2)	<0.001	8.7 (7.6, 9.9)	<0.001
	Difference in growth relative to beneficiaries never in MSSP (pp)		**Difference in growth relative to beneficiaries never in MSSP (pp)**	
Always in MSSP	-0.3 (-0.7, 0.0)	0.085	-0.1 (-0.5, 0.2)	0.436
Entered MSSP	1.9 (1.3, 2.4)	<0.001	1.4 (0.6, 2.2)	<0.001
Exited MSSP	4.5 (3.5, 5.5)	<0.001	3.0 (1.8, 4.1)	<0.001
	Difference in growth relative to beneficiaries always in MSSP (pp)		**Difference in growth relative to beneficiaries always in MSSP (pp)**	
Entered MSSP	2.2 (1.6, 2.8)	<0.001	1.6 (0.7, 2.4)	<0.001
Exited MSSP	4.8 (3.8, 5.9)	<0.001	3.1 (1.9, 4.3)	<0.001
	Difference in growth relative to		**Difference in growth relative to**	

	beneficiaries entering MSSP (pp)		**beneficiaries entering MSSP (pp)**	
Exited MSSP	2.7 (1.5, 3.9)	<0.001	1.6 (0.0, 3.1)	0.046

SOURCE: Authors' analysis of 2012-2014 data from: 20% sample of Medicare claims; the American Community Survey; CMS' Beneficiary-level Shared Savings Program File.
NOTES: Comparisons of beneficiaries who were always in the MSSP (through 2014), entered the MSSP (in 2014) or exited the MSSP (in 2014) were restricted to ACOs that entered MSSP contracts in 2012 or 2013. We excluded beneficiaries who formed ACOs that entered MSSP contracts in 2014, as we could not observe subsequent exit or entry in ACOs formed in 2014 using 2008-2014 data. Differences in risk score growth were examined using a linear spline model that included market fixed effects, year fixed effects, the previously described beneficiary characteristics, beneficiary MSSP status (always vs. never vs. enter vs. exit), splines for the years 2012-2013 (when no entry or exit occurred) and 2013-2014 (when entry or exit could occur), and an interaction between MSSP status and the two splines. We then tested for differences in risk score growth estimated from this fully-interacted spline model. MSSP is Medicare Shared Saving Program.

Exhibit A11. Decomposition analysis of contribution of risk score growth vs. levels to MSSP exit

MSSP exit	Average marginal effect (95% CI)	Relative contribution (95% CI)
Beneficiary exit		
Risk score growth	5.10 (4.43, 5.76)	73% (71%, 76%)
Risk score levels	1.85 (1.58, 2.13)	27% (24%, 29%)
Clinician exit		
Risk score growth	2.09 (0.02, 4.16)	44% (20%, 68%)
Risk score levels	2.67 (1.66, 3.67)	56% (32%, 80%)

SOURCE: Authors' analysis of 2012-2014 data from: 20% sample of Medicare claims; the American Community Survey; CMS' Beneficiary-level Shared Savings Program File.

NOTES: We estimated beneficiary exit in the year 2014 as a function of risk score growth (2012-2014), prior-year risk score (2013), beneficiary characteristics, and market and year fixed effects (n=243,066). To estimate the average marginal effect of risk score growth, we pooled the average marginal effects of risk score growth across four moments of risk score growth (mean, 75th, 95th, and 99th percentile of risk score growth), holding risk score levels at the mean. To estimate the average marginal effect of risk score levels, we pooled the average marginal effects of risk score levels across four moments of risk score levels (mean, 75th, 95th, and 99th percentile of risk score growth), holding risk score growth at the mean. We performed an analogous decomposition analysis of clinician exit in the year 2014. MSSP is Medicare Shared Saving Program. ACO is accountable care organization.